

USAWC STRATEGY RESEARCH PROJECT

EFFECTIVE TECHNOLOGY INSERTION: THE KEY  
TO EVOLUTIONARY ACQUISITION PROGRAMS

by

Mr. Thomas L. Guinivan  
Department of Army Civilian

Colonel Donald Yates  
Project Advisor

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U.S. Army War College  
CARLISLE BARRACKS, PENNSYLVANIA 17013

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## ABSTRACT

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Rapid technological change and a constant evolution in capabilities for new weapon systems present a formidable challenge for acquisition Program Managers, who are responsible for producing a system with the latest technology in a short time frame. Newly acquired systems must have the capability to be upgraded as better technology emerges and user requirements change. This SRP analyses the problems inherent in this challenge, describes the process currently utilized by the Department of Defense (DoD) to address these problems, reviews private industry solutions, and offers recommendations for effective technology insertions in evolutionary acquisition programs.



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## EFFECTIVE TECHNOLOGY INSERTION: THE KEY TO EVOLUTIONARY ACQUISITION PROGRAMS

The major institutions of American national security were designed in a different era to meet different requirements. All of them must be transformed. ...Innovation within the armed forces will rest on experimentation with new approaches to warfare, strengthening joint operations, exploiting U.S. intelligence advantages, and taking full advantage of science and technology.

—The National Security Strategy of the United States  
September 2002

### THE IMPETUS FOR CHANGE

The National Security Strategy advocates dramatic changes in the security needs of our nation. The Department of Defense (DoD) is transforming to meet the challenges of the 21<sup>st</sup> century. To take full advantage of science and technology, DoD must place the best possible technology in the hands of the soldiers, sailors, airmen, Marines and civilians who will conduct and support future military operations<sup>1</sup>. Accelerating the flow of appropriate technology to the warfighter is one of the top priorities of the Under Secretary of Defense (Acquisition, Technology and Logistics)<sup>2</sup>, as well as the services, defense agencies and other key defense organizations that help transition technology. The insertion of state-of-the-art technology into our existing and future weapon systems is also an important recommendation of the Quadrennial Defense Review Report<sup>3</sup> and the Transformation Planning Guidance<sup>4</sup>.

Technology transition or insertion offers the acquisition community an effective way to meet the warfighter's requirements at the lowest possible total cost.<sup>5</sup> To this end, the goals of technology insertion are to use available resources to:

- Leverage the best technology available from both government and commercial sources;
- Rapidly transition the technology into new weapons and other military systems;
- Refresh the technology, as needed, to maintain the advantages that our warfighters need throughout the life of the system;
- Protect sensitive leading edge research and technology against unauthorized or inadvertent loss or disclosure.<sup>6</sup>

This SRP addresses the first three goals.

Three main factors have prompted the use of technology insertion in DoD acquisition programs. First are the changes in DoD and commercial research and development (R&D) funding and programs. The pace of technological change has obviously greatly accelerated in recent years, especially in information management and communication. Technology life cycles,

which were formerly measured in years, now range 12-18 months. Also commercial spending for R&D has increased substantially in recent years, while federal government spending has remained constant. According to data from the DoD<sup>7</sup> and the National Science Foundation<sup>8</sup>, the federal government's share of total R&D funding dropped from 38 percent in 1993 to 26 percent in 2000. In 1993 the federal government share was \$64 billion out of a total of \$166 billion. In 2000 this funding level was still at \$65 billion, while the U.S. total had risen to \$245 billion.

DoD accounts for almost half of the total federal funding for R&D, and DoD is the single largest sponsor of R&D. This decrease in DoD R&D funding coupled with the decrease in DoD procurement over the past ten years led to a dramatic decrease in the influence DoD has on the direction of technology and R&D and its importance in overall markets. For example, DoD now procures less than one percent of the semiconductors worldwide, a smaller share than the automotive industry<sup>9</sup>.

DoD's unique requirements now have little effect on the overall commercial market, so DoD must now use commercial technology in its military systems. Thus the lead for development of critical technologies, which DoD needs to transform its systems, has shifted from the defense industry to the commercial sector<sup>10</sup>. There are basically four types of private firms that conduct R&D, which may be useful to DoD: large traditional defense contractors, non-traditional large firms, traditional small defense firms and non-traditional small firms.

Because of private industry's emerging role as the leader in the commercial R&D sector, DoD is actively seeking access to the technology being developed by the non-traditional firms. Eighty two percent of commercial R&D and 60.5 % of the patents come from large businesses in the commercial sector<sup>11</sup>. DoD is also interested in small business R&D because of their relatively large investment in R&D (\$33 billion in FY00) and the fact that they filed for 39.5% of U.S. patents in 1999. The number of traditional small defense firms is large; they are a proven resource to DoD in their role as subcontractors to the large defense firms. The flexibility inherent in small firms makes them a potentially valuable partner in technology insertion.

Another important DoD consideration is the worldwide diffusion of technology and information. Our current and potential adversaries may have access to our defense technology because the technology is now located in the commercial sector and because U.S. firms no longer are the leader in many areas of technology. For example, during the period of the National Science Foundation study discussed earlier, the level of Japanese and European R&D combined rose from \$225 billion to over \$400 billion dollars.

A second factor prompting DoD's use of technology insertion is the shift from threat based warfighter requirements to those based on capabilities. The most recent QDR asserts that:

A central objective of the review was to shift the basis of defense planning from the “threat-based” model that has dominated thinking in the past to a “capabilities-based” model for the future. This capabilities-based model focuses more on how an adversary might fight rather than specifically whom the adversary might be or where a war might occur. It recognizes that it is not enough to plan for large conventional wars in distant theaters. Instead, the United States must identify the capabilities required to deter and defeat adversaries who will rely on surprise, deception, and asymmetric warfare to achieve their objectives.<sup>12</sup>

We must now assume that our current and potential enemies will attempt to take advantage of our vulnerabilities rather than confront our overwhelming conventional force structure. Further it is assumed that they will use emerging technologies to negate or neutralize our current technological edge.

The third factor prompting DoD's use of technology insertion is the attempt to shorten our current acquisition process, which has come under fire for long development cycles during which the technology used in a new weapon system or commodity became obsolete as the product is acquired and fielded. This problem not only results in weapon systems that are aged technologically when they arrive on the battlefield, but also contain parts that are at or near obsolescence<sup>13</sup>. The following statement from the PM for the new Joint Tactical Radio System (JTRS) illustrates this fact:

The dramatic pace of advances in communications technology coupled with the military's traditional long system-acquisition cycles has resulted in technological obsolescence of new systems before they are fielded. Costs have prohibited retrofitting old systems with improved capabilities, resulting in reduced military readiness.<sup>14</sup>

The three foregoing factors clearly support DoD's initiative to incorporate technology insertion into its acquisition process as a critical contribution to military transformation.

### **TECHNOLOGY INSERTION IN PRIVATE INDUSTRY**

In 2002 the Army War College reviewed several GAO reports designed to identify best industry and commercial practices for potential adoption in DoD acquisition programs.<sup>15</sup> GAO found that DoD accepts much greater risk than the commercial sector because it enters the product development cycle with less-proven technologies and a willingness to mature the technology as part of the development cycle. In the commercial sector, technologies must meet performance and producibility standards within program cost and schedule goals before the product moves to development. GAO concluded that the reason DoD programs are launched earlier is due partly to the fact that establishing a formal program is necessary to attract funds needed to develop the new system. Interviews with several business managers were conducted

to verify this finding. These interviews confirm this important distinction between technology insertion in DoD and private industry.<sup>16, 17</sup>

## **EVOLUTIONARY ACQUISITION AND SPIRAL DEVELOPMENT**

In response to changing requirements and criticism of existing programs, DoD has markedly changed its guidance on the objectives and operation of the defense acquisition system. DoD Directive 5000.1 states that the following policies shall govern all programs: (1) Flexibility, (2) Responsiveness, (3) Innovation, (4) Discipline and (5) Streamlined and Effective Management. These attributes have always been more or less part of DoD guidance, but DoD's new focus is in the area of responsiveness. The policy declares that, " Advanced technology shall be integrated into producible systems and deployed in the shortest time practicable.

Approved time-phased capability needs to be matched with available technology and resources to enable evolutionary acquisition strategies. Evolutionary acquisition strategies are the preferred approach to satisfying operational needs. Spiral development is the preferred process for executing such strategies".<sup>18</sup> But, what does this new strategy really entail? And how does spiral development work as a process?

First of all, evolutionary acquisition and spiral development are not new concepts even in DoD. They were considered as early as 1983 by the acquisition community, and they were endorsed by the Joint Logistics Commanders for use on Command and Control (C2) systems in 1987 because of the rapid technological change even then in information management and communications<sup>19</sup>. DoD Instruction 5000.2 specifically cites the concepts:

An **evolutionary approach** delivers capability in increments, recognizing, up front, the need for future capability improvements. The objective is to balance needs and available capability with resources, and put capability in the hands of the user quickly. The success of the strategy depends on consistent and continuous definition of requirements, and the maturation of technologies that lead to disciplined development and production of systems that provide increasing capability towards a materiel concept...**Spiral development**. In this process, a desired capability is identified but the end state requirements are not known at program initiation. Those requirements are refined through demonstration and risk management; there is continuous user feedback; and each increment provides the user the best possible capability. The requirements for future increments depend on feedback from the users and technology maturation.

The concepts are illustrated in Figure 1. Evolutionary acquisition differs from the current acquisition program strategy in that it delivers the capability in increments to the user, thereby recognizing the need for future capability improvements. It provides for fielding of one or more additional increments based on user feedback, current technology and/or changes in

capabilities required. In contrast to this incremental approach, current programs require a longer development time to provide the required capability in one increment. During this longer development time, in many cases, the pace of technology has rendered the entire system obsolete. Additionally this incremental approach to system development allows for the insertion of new technology in each increment, or spiral, as needed and if available. This ability to insert new technology during incremental development along with reduced delivery time to the user, has prompted DoD to advocate the evolutionary acquisition strategy.

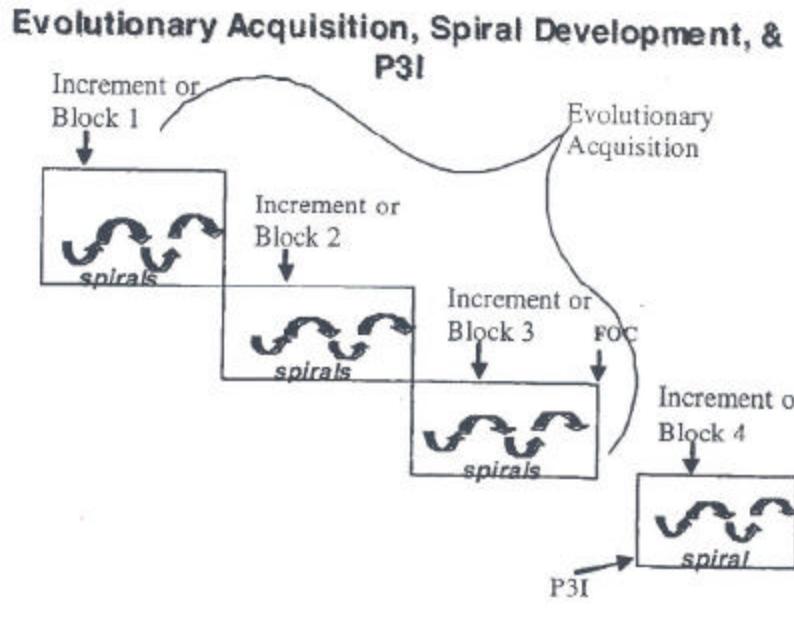


FIGURE 1 – EVOLUTIONARY ACQUISITION MODEL

How does spiral development as a process and as part of the evolutionary acquisition strategy compare with the traditional one block strategy? Each spiral represents the same process as in the single block process, but on a smaller and time-compressed scale. During each spiral increment, the concept, including requisite technology, is selected that best supports activities leading up to Milestone B in the old system. Then the concept is developed into a system for testing and fielding. This sector of the spiral corresponds to traditional process activities conducted between Milestones B and C. Both processes then have a fielding and sustainment part.

What is the difference between spiral development and Pre-Planned Product Improvement (P3I)? P3I is a traditional acquisition strategy that allows for adding improved capability to a mature (meets full capability requirements of the user) system<sup>20</sup> but in spiral development, each increment provides an opportunity to achieve full capability.

### **STAKEHOLDER CONCERNS WITH THE EVOLUTIONARY ACQUISITION PROCESS**

The implementation of evolutionary acquisition (EA) may effect the balance of power between the acquisition community and other DoD organizations and Congress. In order to execute the program, the PM must consider the political and institutional dimensions of their programs - concerns unique to defense acquisitions. A recent article addresses this issue directly: "The ultimate success of the EA policy relies fundamentally on the actions and reactions of a few key institutions within the defense establishment".<sup>21</sup> These institutions include Congress, the military departments, the defense industry, the comptroller community, the requirements writers, operational users, and the test and evaluation community. In addition, the DoD guide to technology transition also discusses the need for the PM to interface with (1) the science and technology (S&T) community, which is part of the defense industry but also contains non defense firms, international firms and government laboratories, and (2) the sustainment community.

Through its power to make laws and appropriate money, Congress wields the ultimate power over the DoD and its acquisition programs. A Congressional Research Service Report for Congress notes that EA is a complex process with built-in uncertainties that pose potentially important challenges for Congress in carrying out its legislative functions, particularly committing to and effectively overseeing DoD weapon acquisition programs.<sup>22</sup> According to this report, Congress wonders whether DoD has sufficient oversight and management of EA programs. Additionally, there is concern about ambiguous initial program descriptions, the lack of well-defined benchmarks, and the more volatile funding projections.

The military departments are interested in viable acquisition programs with stable funding. EA programs with incremental designs and deliveries will probably require more oversight and present funding challenges especially for undetermined follow-on increments.

The defense industry, like all businesses, is interested in long-term profitability, but seems cautiously optimistic about the EA process. The industry has raised two principal concerns. First, EA lends itself to smaller production contracts, but traditionally their best profit margins come with large production contracts. Second, the technology insertion process works well with

competition during the development phase, and the defense industry is concerned about the contracts for the follow-on blocks or increments.

The DoD Comptroller controls the Program Objective Memorandum (POM) process which is used to develop the defense portion of the President's budget. For this community, a program is well-managed when there is a strict accounting for all funds, so EA programs' provision for free floating innovation funds or technology investments tends to be viewed quite negatively.<sup>23</sup> The Comptroller has asked a series of questions related to the funding transition between blocks or increments. Also there have been questions about full funding for programs if the requirements are not known at program initiation. The Comptroller also wonders whether each block or increment could be independently priced.

The users of the system, the requirements and operational community, previously developed requirements documents in which the final required capability was known. Now they must develop requirements for EA programs wherein the final capability may not be known in detail or if it is known, the technology may not yet be available to field that capability. The challenge now for the PM and user is to develop a realistic phased approach to meet the final required capability. The user must be able to accept that the first increment fielded may be the 50 to 80% solution, with further increments contributing toward the required capability.

The test and evaluation community has the responsibility to insure through valid testing that the prototype system will have the required capabilities under operational conditions. The entire process of developmental and operational testing is markedly different with EA programs. Sylvester and Ferrara, in their article on EA implementation, describe the situation well:

The testing regime is based on the idea of a grand design in which a single system will be produced, initially at low rate, and then subject to comprehensive testing before being permitted to move to full rate production. As the Department has moved to evolutionary acquisition, the role of operational test and evaluation has become more ambiguous. Evolutionary acquisition provides multiple increments of capability, each to be deployed over time. While the need to determine if the system still works for each increment, the cost and time to conduct dedicated operational tests on each increment and what to test with each increment is open to discussion.<sup>24</sup>

As described in the USD (AT&L) guide, the science and technology (S&T) community includes not only industry and academia involved in R&D but also the government scientists and managers of S&T programs.<sup>25</sup> Their greatest concern is that funding and business arrangements must be available for research, especially basic research. Then there is a two-way communication challenge: First, the PM and his staff need to be aware of the emerging

technologies which may be available for insertion into the system; and second, the researchers, both private and public, must be informed of the DoD technology requirements.

Many of our currently fielded systems now have planned life cycles of 20 years or more. The sustainment or logistics community is responsible for supporting newly fielded systems. The EA process presents a problem for sustainment in that several increments or versions of a system are being fielded in a few years time span, whereas the old acquisition process fielded only one system per program. So EA presents problems with configuration control and management as well as the purchase, storage and distribution of spare parts and other support items. Also the logistics community is concerned about frequent changes in design because it is important that each design consider the long-term supportability of the system.

Given these stakeholder concerns, how should the Program Manager execute the program, including the insertion of technology? And what tools and processes are available to support the EA PM?

### **EXECUTION OF A EVOLUTIONARY ACQUISITION PROGRAM**

The Program Manager uses essentially a seven-step process to execute a spiral or increment within an evolutionary acquisition program. Political, technical and administrative challenges are associated with each step:

- Determination of the required capabilities of the user
- Development of an acquisition strategy that addresses funding, technology determination, technology insertion, development, test and evaluation, production, logistics/sustainment, additional increments and the contracts for the program
- Review of available technology vs. program requirements
- Determination of appropriate technology and insertion into program
- Development and testing of a prototype system
- Production and fielding of the new system
- Input from field and decision on next increment or spiral

An essential component to the success of all seven steps is communication among all of the government and private organizations involved in the program. This communication is formally facilitated by the Integrated Product and Process Development (IPPD) process, which is mandated in acquisition program guidance. The IPPD is a management process which brings all of the industrial and government organizations together from the beginning of the program, allowing them collectively to address development, production, testing and sustainment issues throughout the process. The IPPD is carried out by Integrated Product Teams (IPTs) that are

cross-functional and multidisciplinary by membership. IPTs should be part of the program from the earliest stages of determining the required capabilities.

Determining a set of required capabilities, which are phased for the program, provides the basis for an evolutionary acquisition program. The user must then agree to the incremental capabilities. The user must understand that the initial fielded system may offer only a 50-80% solution due to the maturity of the technology or other factors. To aid the PM, the Joint Staff has issued a new Chairman's Instruction (CJCS Instruction 3170.01) that has adopted time-phased or evolutionary requirements as standard practice for developing and writing operational requirements. But there still is a lot of ambiguity and uncertainty about the application of the policy at the program level<sup>26</sup>. A pitfall to be avoided in this process is the front loading of the requirements by the user who questions the long-term viability of the program and doubts that incremental development will field the desired system. Front loading defeats the whole purpose of evolutionary acquisition.

The program acquisition strategy enables PMs to effectively address the oversight and policy concerns of Congress, the military departments and the DoD Comptroller. But, the strategy for an EA program must address three major issues not found in traditional acquisition planning: First, based on the required capabilities, the plan must include the use of anticipated incremental upgrades to the system. Second, the plan must accurately specify anticipated funding increments; and third, the plan must include insertion of emerging technology into one or more increments. The planned increments or spirals must offer enough specificity in terms of capabilities to justify the allocation of out-year funding and to communicate to the S&T community a schedule of technology requirements for insertion into acquisition programs. DoD's budget process requires the PM to project funding requirements at least 18 to 24 months in advance. Since the funds are available for two years, the PM and S&T must communicate early and often to make sure funding is available for maturation of the technology and insertion into the program with no break in the funding stream. Recently the DoD Comptroller has redefined budget categories for advanced development (6.3a and 6.3b funding) to allow work to be done without an operational requirements document<sup>27</sup>. This gives the S&T community and the PM more flexibility in the technology transition funding. As in previous plans, the PM must address sustainment, development, testing, production and fielding of the increments. Also, as directed in the recent DoD policy, the PM should include competition wherever possible in the contract strategy.

DoD has a wide range of programs and business arrangements in place to provide funding and other assistance to government and private firms doing basic and applied research.

In addition, many programs are designed to provide information to the Program Manager about emerging government and private technologies and to provide the researcher with the current DoD technology requirements. Appendix B of the USD (AT&L) guide to technology transition provides information on approximately fifty government, industry and academic websites with information on current technology and basic research efforts.<sup>28</sup>

Even though the information on current technology is available, a recent DoD study found that "it remains very challenging for a PM to find timely, reliable and pertinent information necessary for program development".<sup>29</sup> Solutions to date include development of service - wide technology information groups and tailored websites at the respective service research labs. Assuming the PM has the information required and has identified several technologies for consideration, the next step is most important in the process - determining the correct technology and implementing a business arrangement or program to insert that technology into the developmental program.

One of the keys to success in evolutionary acquisition practiced in the commercial sector is to insert a technology that is sufficiently mature to be fielded in a relatively short period of time with acceptable risk. DoD has developed a method for measuring the maturity of technology called the Technology Readiness Levels or TRLs. It assigns a numerical rating of 1 to 9 to the technology, based on various criteria. Table 1 lists the TRLs and the description of each level. A 1999 GAO report found that successful programs used technology with a TRL rating of 6 to 8<sup>30</sup>. So now Program Managers should select technologies for insertion on the basis of their TRLs.

Technology readiness level	Description
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples are paper studies of a technology's basic properties.
2. Technology concept or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and proof or detailed analysis might not be available to support the assumptions. Examples are limited to analytical studies.
3. Analytical and experimental critical function or characteristic proof of concept.	Research and development is initiated, including analytical and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Validation of component or prototype in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of ad hoc hardware in the laboratory.
5. Validation of component or prototype in relevant environment.	Fidelity of prototype technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System or subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.

Technology readiness level	Description
7. System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle, or space. Examples include testing the prototype in a test-bed aircraft.
8. Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system proven through successful mission operations.	Application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Source: DoD 5000.2-R, April 5, 2002.

Definitions used in the TRL and EMRL matrices:

**Brassboard:** An experimental device (or group of devices) used to determine feasibility and to develop technical and operational data. It normally is a model sufficiently hardened for use outside of laboratory environments to demonstrate the technical and operational principles of immediate interest. It may resemble the end item, but is not intended for use as the end item.

**Breadboard:** integrated components that provide a representation of a system/subsystem and which can be used to determine concept feasibility and to develop technical data. Typically configured for laboratory use to demonstrate the technical principles of immediate interest. May resemble final system/subsystem in function only.

**"High fidelity":** addresses form, fit and function. High-fidelity laboratory environment would involve testing with equipment that can simulate and validate all system specifications within a laboratory setting.

**"Low fidelity":** a representative of the component or system that has limited ability to provide anything but first order information about the end product. Low-fidelity assessments are used to provide trend analysis.

**Model:** a functional form of a system, generally reduced in scale, near or at operational specification. Models will be sufficiently hardened to allow demonstration of the technical and operational capabilities required of the final system.

**Operational environment:** environment that addresses all of the operational requirements and specifications required of the final system to include platform/packaging.

**Prototype:** a physical or virtual model used to evaluate the technical or manufacturing feasibility or military utility of a particular technology or process, concept, end item or system.

**Relevant environment:** testing environment that simulates the key aspects of the operational environment.

**Simulated operational environmental:** either 1) a real environment that can simulate all of the operational requirements and specifications required of the final system, or 2) a simulated environment that allows for testing of a virtual prototype; used in either case to determine whether a developmental system meets the operational requirements and specifications of the final system.

TABLE 1 – TECHNOLOGY READINESS LEVELS

Next comes selection and implementation of a program or agreement to facilitate the transition. A technology transition plan is an essential part of the overall program acquisition strategy. DoD guidance stipulates this plan should contain the following elements:

- Description of technology pathway in detail
- Expected outcomes of the project, including measurable outcomes and achievable exit criteria
- Funding strategy which names resources to be provided by source, amount and timing
- Schedule and milestones, including a transition or handoff schedule
- Identification of the “customer”
- Acquisition strategy and integration plan
- Issues and risks for cost, schedule, technical development, manufacturing, and sustainment
- Signed agreement between PM and “customer” for funding, schedule and deliverables
- “Customer” funding strategy for acquisition and fielding
- Plan from multiple sources for using the technology and encouraging innovation in the program<sup>31</sup>

This plan must be tailored to the needs of participant or “customer”. The transition of a technology under development in a government lab is the least complex PM task. It requires an agreement between the organizations but doesn’t involve intellectual property or funding transfer. But the agreement to transition technology from private industry, especially from non-traditional firms and small defense firms, must address their reluctance to doing business with the DoD. They are concerned about intellectual property rights, long product development times and the amount of reporting, auditing and oversight connected with the contracts.

The issue of intellectual property rights has been the subject of recent testimony before Congress by the GAO<sup>32</sup> and the Small Business Technology Coalition.<sup>33</sup> Business, especially small research firms, are not willing to enter into contracts by means of which any or all of their proprietary technical information becomes available for public use because this information provides their competitive edge in the market. Transition of technology with academia must also address intellectual property issues but there is more flexibility in these arrangements because academic researchers are not involved in a for-profit organization.

The USD (AT&L) guide also provides an excellent summary of available programs and business arrangements for dealing with private industry, academia, and government organizations.<sup>34</sup> Depending on the type of end product required by the PM, there are basically six business arrangements available for use with academia and private industry: contracts, grants/cooperative agreements, cooperative R&D agreements, other transactions for prototype

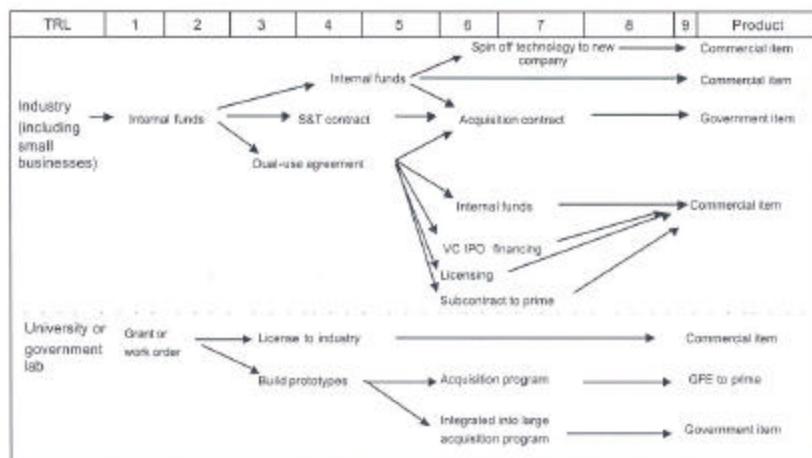
projects (OTs), technology investment agreements (TIAs) and venture capital programs. In addition, the following DoD programs have been developed for technology transition with industry: Advanced Technology Demonstrations (ATD), Advanced Concept Technology Demonstration Programs (ACTD), the Dual-Use Science and Technology (DUST) Program, the Joint Experimentation Program, the Small Business Innovation Research (SBIR) Program, the Small Business Technology Transfer (STTR) Program, the Defense Acquisition Challenge Program, the Warfighter Rapid Acquisition Program (WRAP) and the Technology Transfer Initiative. PMs can access much information on these alternatives within DoD. Utilizing this information, they can select appropriate pathways to technology transition as shown in Figure 3. They are then prepared to implement a program to execute the technology transition. Of course, contracting officers must have a good working knowledge of the alternatives and must assure that an acquisition strategy for the program has been formulated for the transition of the technology.

Acquisition requirements are generally satisfied through a procurement contract. Contracts are normally used with traditional defense contractors from whom the government wants a deliverable end product. Federal procurement contracts are based on the Federal Acquisition Regulation (FAR) and the Defense Federal Acquisition Regulation Supplement (DFAR). R&D contracts are usually executed based on Part 15 of the FAR. The Federal Acquisition Streamlining Act created FAR Part 12, Acquisition of Commercial Items, to promote the purchasing of commercial items, including R&D services, and to attract commercial firms to do business with the government.<sup>35</sup> Recent legislative action offers incentives for using Part 12 when buying performance-based services. The drawback to this type of contract is that it must specify a fixed price, so the PM should consider this option for a well-defined research program with known milestones or a contract for lab or testing services.

Grants and cooperative agreements are normally used with academia or non-profit organizations for basic research. The principal purpose of a grant or cooperative agreement is to provide assistance in research. Products of these agreements include research reports and training. For DoD, the controlling regulation for these types of documents is the DoD Grants and Agreement Regulation (DODGAR) as contained in 32 CFR, Part 21,22,25,32, and 34.<sup>36</sup>

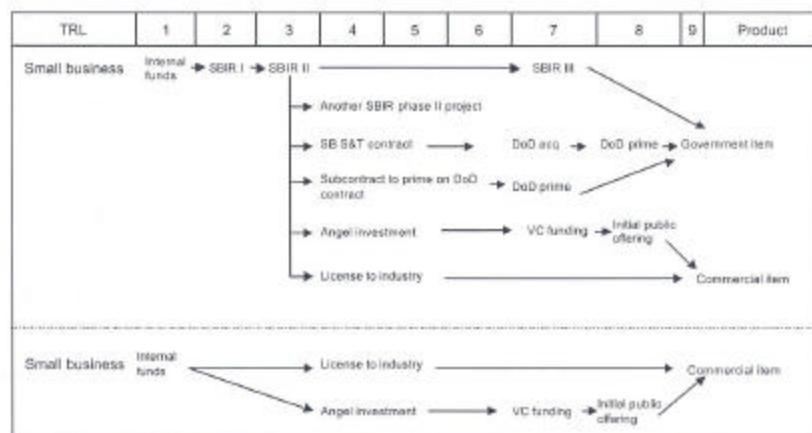
Cooperative Research and Development Agreements (CRADA) provide a way to conduct specific R&D activities, consistent with the DoD mission, with non-federal partners, such as industry and academia. A CRADA establishes a working relationship between one or more DoD labs or technical activities and one or more non-federal parties. These parties may exchange intellectual property, expertise or data. They may also exchange the use of personnel, services,

materials, equipment and facilities. The rights to invention and intellectual property are flexible and are negotiated as part of the agreement.<sup>37</sup>



Note: "Pathways to transition" outlines the major funding decision points in relationship to DoD technology readiness levels (TRLs). The TRLs shown are representative of typical decision points, but are not fixed. "Contract" means a contractual instrument appropriate for the situation, such as FAR Part 12, FAR Part 15, modifications (e.g., value engineering change proposals), or other transactions.

Figure D-2. Small Business-Unique Pathways to Transition



Note: "Pathways to transition" outlines the major funding decision points in relationship to DoD TRLs. The TRLs shown are representative of typical decision points, but are not fixed. "Contract" means a contractual instrument appropriate for the situation, such as FAR Part 12, FAR Part 15, modifications (e.g., value engineering change proposals), or other transactions.

FIGURE 2 – PATHWAYS TO TECHNOLOGY TRANSITION

DoD has established a subset of the TIA authority which is called “other transactions for prototype projects”. This authorization, which has sunset provisions, is set forth as an amendment to 10 U.S.C. 2371, Section 845 of PL 103-160. This amendment specially authorizes using OTs for prototype projects which are directly relevant to weapons or weapon systems to be acquired or developed by DoD. In general, OTs for prototype projects are not subject to federal laws and regulations governing procurement contracts. Thus they provide PMs with flexibility in accounting practices, auditing, subcontracts, performance-based payments and other terms and conditions. There is extensive information available to the PM for this type of contract.<sup>38</sup>

Venture Capital (VC) is an emerging DoD program. It is used in acquiring innovative technology. It invests in high-risk/high-payoff technologies in hopes of shaping the technology upfront. In the 2002 Defense Appropriation Act, Congress directed the Army to establish a \$25 million non-profit VC company to focus on the provision of electric power to the infantry. Congress also directed the Navy to consider using VC.<sup>39</sup>

Advanced Technology Demonstration (ATD) is the process for managing selected high-priority S&T programs. ATD brings a team together early to monitor and consider applications of emerging technologies that demonstrate a military capability. ATDs are used to accelerate the maturation of technologies needed by the warfighter. The senior research and technology manager in an organization manages ATDs, which are developed and nominated for selection and funding at the service level.

By contrast, Advanced Concept Technology Demonstration programs or ACTDs are actual programs that are reviewed, approved and funded at the OSD level. ACTDs are designed to enable their users to understand the new proposed capabilities for which there is no user experience.<sup>40</sup> These programs give the warfighters the opportunity to develop and refine the concept of operations to fully exploit the new technology; to develop and incorporate the warfighter's operational requirements; to operate prototype systems in realistic military demonstrations; and to assess the military usefulness of the proposed capability. The Joint Experimentation Program works closely with ACTD programs and is used to shape concepts, doctrine and materiel systems requirements for the future joint force. This program focuses a great deal on interoperability of systems.

The purpose of the Dual Use Science and Technology (DUST) Program is to develop partnerships with industry to jointly fund the development of dual-use technologies needed by DoD. It promotes streamlined contracting procedures and cost sharing among the services,

OSD and industry. In 2001, the DUSD (Science and Technology) published a guide for implementation of this type of program.<sup>41</sup>

Two programs are designed to help small businesses participate in federal R&D: the Small Business Innovation Research (SBIR) Program and the Small Business Technology Transfer (STTR) Program. The programs are similar; both select participating companies from solicited proposals. Both programs have a two-phased funding strategy which provides initial funding for a concept followed by additional funds if the concept is found to have scientific, technical and commercial merit and feasibility<sup>42</sup>.

The Warfighter Rapid Acquisition Program (WRAP) was created by the Army to address the gap in funding, usually two years at best, that exists because of the time to plan, program, budget and receive funding for procuring a new technology. Programs are selected at the service level to receive funding in the execution year for up to two years, which allows the program to continue while funds are being placed in the budget for funding. Selection is based on the urgency of need, technical maturity, affordability and effectiveness. The Army no longer funds the program, but there is an active Air Force WRAP program.

The FY 03 Defense Authorization Act has created two new programs that are intended to introduce new technology into DoD's acquisition programs: the Defense Acquisition Challenge Program and the Technology Transition Initiative. Procedures for both programs are currently under development. The first program will give people or organizations inside or outside of DoD the opportunity to propose alternatives, or challenge proposals, to an existing DoD acquisition program. Alternatives should improve the performance, affordability, producibility, or operational capability of the program.<sup>43</sup> The stated objectives of the second program are to accelerate the transition of new technologies and to successfully demonstrate new technologies in relevant environments.<sup>44</sup>

One important additional consideration for the PM in the transition plan is the use of competition. DoD guidance encourages competition and in testimony before Congress, Richard Carroll, the Chairman of the Small Business Technology Coalition asserted: "It is my profound belief that the best way to bring innovation, affordability and rapid transition of technology into defense systems is to create more competing alternatives".<sup>45</sup> A recent Army War College study concurred.<sup>46</sup>

Once the technology has been transitioned, the spiral development process is initiated. This is intended to be an iterative process of development, testing, and feedback leading to more development, if required, until the system meets the incremental capability and is ready for production and fielding. During development, the sustainment and supportability of the system

must be addressed in the design. One lesson learned in this area is the need for an open architecture and design so that modifications to improve the capability of the system can be done by replacement of subsystems or modules, rather than a complete redesign and modification of the system.<sup>47</sup> An equally important part of the phase of the program is the test and evaluation (T&E) of the prototype system(s). A T&E plan is part of the acquisition strategy.

A new issue with EA programs has been the amount of risk that Program Managers have been willing to accept by reducing the amount of testing. In a recent article, the Director of the OSD Operational Test and Evaluation Office notes that during the 1997-2000 time period, 80% of the Army systems were unable to meet 50% of the reliability requirements during operational

EM readiness level	Description
1. System, component, or item validation in laboratory environment or initial relevant engineering application or breadboard, brass board development	Significant system engineering or design changes. System engineering requirements not validated. Physical and functional interfaces not defined. High program risk. Materials tested in laboratory environment. Machines and tooling demonstrated in laboratory environment. Manufacturing processes and procedures in development in laboratory environment. Quality and reliability levels and key characteristics not yet identified or established. Includes requirements of TRL 4 and TRL 5 as a minimum.
2. System or components in prototype demonstration beyond breadboard, brass board development.	Many systems engineering and design changes. Systems engineering requirements validated and defined. Physical and functional interfaces not fully defined. High program risk. Risk assessments initiated. Materials initially demonstrated in production. Manufacturing processes and procedures initially demonstrated. Machines and tooling require major investment. Inspection and test equipment developed and tested in manufacturing environment. Quality and reliability levels and key characteristics initially identified. Includes requirements of TRL 6 as a minimum.
3. System, component, or item in advanced development. Ready for low-rate initial production.	Few systems engineering or design changes. Prototypes at or near planned system engineering for required performance levels for operational system. Physical and functional interfaces clearly defined. Initial risk assessments completed. Moderate program risk. Materials in production and readily available. Manufacturing processes and procedures well understood and ready for low-rate initial production. Moderate investment in machines or tooling required. Machines and tooling demonstrated in production environment. Inspection and test equipment demonstrated in production environment. Quality and reliability levels and key characteristics identified, but not fully capable or in control. Includes requirements of TRL 7 as a minimum.
4. Similar system, component, or item previously produced or in production. System, component, or item in low-rate initial production. Ready for full-rate production.	Minimal systems engineering or design changes. All systems engineering requirements met. Minimal physical and functional interface changes. Initial risk assessments complete. Low program risk. Materials available. Manufacturing processes and procedures established and controlled in production to 3-sigma level. Minimal investment required in machines or tooling. Machines, tooling, and inspection and test equipment deliver 3-sigma quality in production. All key characteristics controlled to 3-sigma level in production. Includes requirements of TRL 8 and 9 as a minimum.
5. Identical system, component, or item previously produced or in production. System, component, or item in full-rate production.	No systems engineering or design changes. Identical system, component, or item in production or previously produced that met all engineering requirement for performance, quality, and reliability. Low program risk. Materials, manufacturing processes and procedures, inspection and test equipment, quality and reliability, and key characteristics controlled in production to 6-sigma level. Proven affordable product.

This table provided courtesy of the Missile Defense Agency.

TABLE 2 –ENGINEERING AND MANUFACTURING LEVELS

testing. Also the Air Force had to stop two thirds of their operational tests because the systems were not ready. The Army also had to stop or postpone many operational tests because systems were not ready.<sup>48</sup> The article poses seven questions that a PM should address to insure that T&E is done properly during development.

Finally the PM needs some working criteria to determine if the system is ready for production, operational testing and fielding. Space and Missile Defense Command has developed Engineering and Manufacturing Levels (EMLs), similar to the Technology Readiness Levels (TRLs), to determine if the prototype is ready for production. See Table 2.

The final two phases in the execution of the program involve production, fielding, feedback from the user and a decision regarding additional increments of spiral development. The production contracts for EA programs consist of several small buys tied to successive increments of development. The production lot size will be dependent on the user and how many systems of initial capability are required for the mission and for user feedback. This is a different approach than was used in defense acquisition for the past twenty plus years and the defense industry is adjusting to this change. The PM will need to tailor the production contracts and funding for this change. Also tied to the T&E planning, a decision will be needed to be made regarding the requirement for Low Rate Initial Production (LRIP) and operational testing before the full lot of systems is produced.

Finally the PM must plan and implement a feedback system from the users in the field of the initial increment system. This information will in large part determine whether an additional development increment is required and what will be the next required increment of capability.

#### **EVALUATION TO DATE OF EVOLUTIONARY ACQUISITION**

Evolutionary acquisition is a relatively new process within DoD. What does the scorecard look like to date? There are documented DoD success stories of systems acquired through EA using technology insertion. The USD (AT&L) guide lists the following large acquisition programs as examples of effective implementation of the process: Evolved Expendable Launch Vehicle (Air Force), Global Hawk (Air Force), DD 21 (Navy) and the Unmanned Combat Aerial Vehicle (DARPA/Air Force).<sup>49</sup> This guide also lists 24 technologies that were successfully transferred using the Dual Use Science and Technology Program. Also 21 companies developed technology for DoD under the Small Business Innovation Research (SBIR) Program and 16 technologies from the Office of Naval Research that were inserted into acquisition programs. The successful use of spiral development in the Global Hawk Program is documented in a recent Acquisition Review Quarterly article.<sup>50</sup> A National Academy of Sciences report in 2000

found that the SBIR Program was achieving its goals of facilitating research by small business for the DoD.<sup>51</sup> On the down side, a DoD IG audit of the Army's transition of advanced technology programs to military applications found that " Acquisition program officials were not adequately involved in fully facilitating and supporting the successful and timely transition to the warfighter...As a result, the Army cannot make fully informed or prudent decisions on whether continued investment is warranted".<sup>52</sup>

## CONCLUSIONS

- Evolutionary acquisition based on technology insertion can offer some unique advantages over the traditional acquisition process.
  - Incremental capabilities can be fielded to the warfighter sooner.
  - Risks can be spread across a series of increments that provide demonstrated capabilities to the user.
  - Lessons learned in the field and in earlier increments can be added to the next increment making the acquisition community more responsive to the user needs.
  - Technology can be inserted faster.
- The primary difference between technology insertion in DoD and private industry is the fact that in the commercial sector, technologies must meet performance and producibility standards within program cost and schedule goals before the product moves to development, but DoD acquired technologies are not subject to such constraints.
- There are numerous stakeholder concerns about the new evolutionary acquisition process in DoD.
- There are tools, programs and funding available to the Program Manager to execute this type of program.
- Program Managers face seven significant challenges to the technology transition:
  - Incremental phasing of capabilities/requirements with the user
  - Awareness of emerging technology to meet program needs
  - Effective contracts which address intellectual property rights and competition
  - Funding for undetermined number of increments and a system without end state capabilities or requirements
  - Testing and evaluation of incremental capabilities
  - Funding and contract vehicles for limited production quantities of incremental systems
  - Logistics and sustainment for incremental systems
- The keys to successful insertion of technology in an evolutionary acquisition program are (1) insuring that the technology is mature before insertion; (2) planning in the

acquisition strategy for the insertion to include contracts, funding, testing, fielding and sustainment; and (3) effective communication with stakeholders that have a vested interests in the program.

## **RECOMMENDATIONS**

- DoD adopt the private industry practice of inserting only mature technology into development programs.
- DoD provide additional training to contracting officers on intellectual property rights provisions and contract options available to DoD to overcome private industry concerns about public disclosure and use of proprietary technical information.
- DoD develop, in coordination with Congress, revisions to the funding guidance for the Programming, Planning, Budgeting and Execution System (PPBES) to address the fact that the content, required capabilities and funding requirements for the follow on increments of evolutionary acquisition programs are subject to change based on technology and user needs.

WORD COUNT= 6,577

## ENDNOTES

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<sup>2</sup> Memorandum from the Under Secretary of Defense (Acquisition, Technology and Logistics) to the Secretary of Defense, Subject: Top 5 Priorities for AT&L, 6 August 2002.

<sup>3</sup> Quadrennial Defense Review Report, 30 September 2001

<sup>4</sup> Transformation Planning Guidance, April 2003

<sup>5</sup> For the purposes of this paper, technology transition and technology insertion are synonymous terms.

<sup>6</sup> Office of the Under Secretary of Defense (Acquisition, Technology and Logistics), *Manager's Guide to Technology Transition in an Evolutionary Acquisition Environment*, version 1.0, (31 January 2003)

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<sup>11</sup> Ibid.

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<sup>20</sup> E.C. Aldridge Jr., Under Secretary of Defense. "Evolutionary Acquisition and Spiral Development" Memorandum for Secretaries of the Military Departments. Washington, D.C., 12 April 2002.

<sup>21</sup> Richard K. Sylvester, and Joseph A. Ferrara, "Conflict and Ambiguity – Implementing Evolutionary Acquisition". *Acquisition Review Quarterly* (Winter 2003): 2-27.

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<sup>24</sup> Ibid.

<sup>25</sup> Office of the Under Secretary of Defense (Acquisition, Technology and Logistics), *Manager's Guide to Technology Transition in an Evolutionary Acquisition Environment*, version 1.0, (31 January 2003)

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<sup>36</sup> Ibid.

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